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Assessment of Lead Accumulation on Soils and Vegetables Grown along Major Roads within Nakuru Town

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Abstract

Lead has been found to be toxic to human beings even at low concentrations due to its negative effects on IQ, impaired hearing, behavioral problems (aggression) and delayed bone growth alongside causing death in some cases. The main objective of the study was to assess levels of lead in soils and vegetables grown along Kipande, Eldoret- Nakuru and Nakuru - Nairobi roads within the Nakuru County. All samples were collected, digested and analyzed for the presence and levels of lead using atomic absorption spectroscopy. The results indicated high levels of lead in analyzed soils to have ranged from 23 to 130 mgPb/Kg which were more than 100 times higher than the recommended lead values in soils by the EPA. Samples of leafy vegetables (kales) were collected and analyzed for residual lead showed levels of lead to range from 1.62 to 6.50 mgPb/Kg with high levels recorded in samples collected along the main roads than in samples collected 60 meters from the roads. The results showed high statistical correlation ($p < 0.05$, $r = 0.9372$) between levels of lead in soils and sampled vegetables. The concentrations of lead in the sampling sites decreased linearly with distance from the edge of the road and dropped to the minimum levels at about 60 meters. The study found that vehicle emissions could be a major contributing factor of high levels of lead in soils and vegetables grown along the main roads under study. It is therefore recommended that growing of vegetables for both human and animal consumption should be discouraged and proper legislation put in place to prevent roadside usage as farmlands in Kenya.

Key words: Lead, Pollution, Emissions, Roadside, Heavy metals.

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Introduction

Roadside soils can act as a sink for heavy metals and other pollutants, with possible sources mainly from anthropogenic activities such as vehicular emissions (Burghardt, 2002), waste water sludges and industrial wastes (Lee *et al.*, 2005). Uncontrolled development and urbanization has also resulted in accelerating input of heavy metals in soils.

In the last few decades, anthropogenic activities like industrial and energy production, construction, waste disposal, domestic heating system and increased motor vehicles on the roads are continuously contributing towards an increase in the level of heavy metals in urban soils (D'Mello, 2003). Heavy metal contents in soil are highly dependent on the geochemical nature of the parent material; their presence in the soil is due to natural weathering of parent rock material and pedogenic processes. Conversely, their accumulation in soils is of considerable importance because they are persistent, non- biodegradable and toxic to biota, if it exceeds to the threshold value (Steenland and Boffetta, 2000).

Soil is one of the chief components of an ecosystem and is the most endangered due to the influence of various human activities related to industrial, agricultural, and urban development (Zaidi *et al.*, 2005). Urban soils vary spatially due to soil composition (Jarup, 2003). Urban areas are expanding all over the world utilizing more and more agricultural and natural areas and changes in land use and land cover are gaining wide recognition as a key driver responsible for environmental change (Steenland and Boffetta, 2000).

In the last two decades, reduction of land cover is attributed to the accelerated rate of urbanization along with explosive economic growth (Zaidi *et al.*, 2005). Land converted to urban land use such as housing, parks, industrial and disposal sites has resulted in loss of cultivated green land and arouses special attention (Nogaim *et al.*, 2013).

Additional input of waste materials, landscaping and rapid change of land use also contributes towards an unpredictable modification of soil properties and poor soil structure increasing concentrations of heavy metals (D'Mello, 2003). Change in land use has important consequences for many biological, chemical and physical processes in soils, and indirectly to its environment due to land use changes, soil pollution has become an important environmental issue in developing countries (Steenland and Boffetta, 2000).

Lead is among the most abundant trace heavy metals in soils and is particularly toxic (Radwan and Salama, 2006). Excessive content of lead in food is associated with a number of diseases, especially those of the cardiovascular, renal, nervous and skeletal systems (WHO, 1992, 1995; Steenland and Boffetta, 2000; Jarup, 2003). It is also implicated as a possible carcinogen, mutagen and teratogen (Radwan and Salama, 2006).

Food safety is a major public concern worldwide. Increasing demand of food safety has stimulated research regarding risks associated with consumption of foodstuffs contaminated by pesticides, heavy metals and/or toxins (D'Mello, 2003). Heavy metals are among the major contaminants of food supply and may be considered the most important problem to our environment. Such problems are becoming more serious all over the world especially in third world countries (Zaidi *et al.*, 2005). Heavy metals in general are not biodegradable, have long biological half-lives and potential accumulation in the different body organs leading to unwanted side effects. Heavy metals are divided into essential (e.g. Cu, Ni, Fe, and Zn) and non-essential (e.g Cd, Pb, Hg, Sn) for living organisms (Santos *et al.*, 2014).

Vegetables are good sources of vitamins, minerals, fibres and are also beneficial to health. As the plants contain both essential and non essential elements, they are also burdened with heavy metals from the use of fertilizers, and pesticides over a wide range of concentrations (Radwan and Salama, 2006). It is well known that leafy vegetables such as *Amaranth palmeri*, *Brassica oleracea*, spinach and *Brassica oleracea Acephala* are said to be good absorbers of heavy metals from soils (Elbagermi *et al*., 2012). This may be a major source of heavy metals to human beings who consume such vegetables on a daily basis.

Human exposure to heavy metals is a subject of public health concern that has attracted the attention of researchers, health and nutrition experts all over the world. The allowable limit of lead as a heavy metal is 0.3 mg/Kg in vegetables and recommendations by WHO/FAO are 40, 0.3, and 0.2 mg/kg respectively (Nogaim *et al*., 2013). Keeping in view the potential toxicity, persistent nature and cumulative behavior, as well as consumption of vegetables, there is a necessity to test and analyze these food items to ensure that the levels of these contaminants meet the agreed international requirements (Radwan and Salama, 2006).

Human activities have significantly increased the global emissions of heavy metals, particularly lead (Pb), in the surface environment (Nriagu and Pacyna, 1988). Lead is among the most hazardous heavy metals that has damaging impact on human and environmental health (Wong 2004). Traffic induced lead, as a result of using leaded gasoline, is one of the major sources of lead in the populated and highly industrialized areas (Fakayode and Olu-Owolabi, 2003).

Due to growing concerns about the problems associated with Pb, the use of leaded gasoline has been decreasing globally at an annual rate of about 7% (Faiz et al., 1996). The maximum level of lead in leaded gasoline has been set to be less than 0.15 g L^{-1} since July 1989 (Nriagu, 1990), but there are still many countries that use leaded gasoline with lead content of about 0.4 g L^{-1} (Faiz et al., 1996; Kaysi et al., 2000). Although the use of leaded gasoline decreased during this period, the increasing number of automobiles compensated its effect. In addition, the wearing down of vehicle tires can also introduce Pb (Giannouli et al., 2007) to the roadside soil. Consequently, road transport is still polluting the atmosphere, soil and water near highways (Caselles, Traffic effect on lead accumulation in soils 12 1998; Fakayode and Olu-Owolabi, 2003; Li, 2006).

Soil represents a major sink for heavy metals in the terrestrial environment. Due to the non-biodegradability and cumulative tendency of Pb, emitted lead from vehicles accumulates in the surface soils in the long run (Sutherland., 2000). The concentration of lead in the roadside soils is influenced by gasoline quality, traffic intensity, as well as meteorological conditions like the temperature, velocity and direction of wind and to some degree by precipitation (Viard et al., 2004). Several studies indicated lead pollution in the surface soil due to the use of leaded gasoline in developed countries (Mellor and Bevan, 1999; Al-Chalabi and Hawker, 2000; Sutherland., 2000; Li, 2006), but the extent of the pollution has not been quantified in developing countries such as Kenya.

The environmental problems associated with leaded gasoline are exacerbated where highways are close to agricultural lands. This is because accumulated lead can be transferred to the food chain by either direct atmospheric fallout on the plants or plant uptake from the soil.

Study Area

The study was done alongside Eldoret - Nakuru, Kipande and Nakuru - Eldoret major roads within Nakuru County, Kenya as in Fig 1. The study area was purposively selected due to high automobile activity and presence of vegetables planted alongside roads within the County.

Sampling Design

The experimental design used involved the determination of levels of lead in both soil and selected vegetable samples (kales) from road sides within Nakuru County. Samples were collected in vegetable farms along Eldoret - Nakuru, Kipande and Nakuru - Nairobi roads. Obtained samples were then air dried, weighed and digested before the digests were analyzed for lead using AAS.

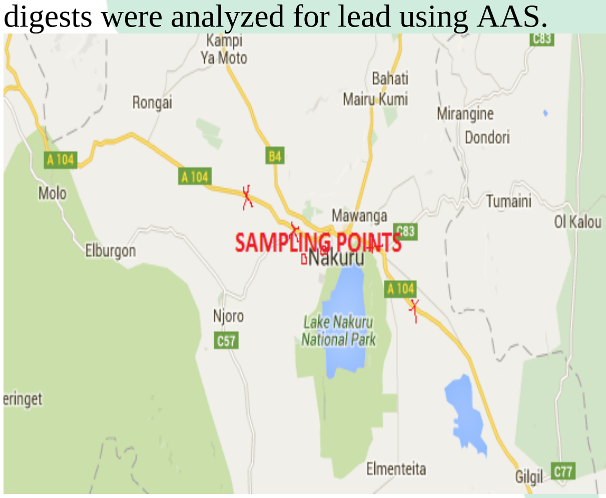

Fig 1. Sampling area of Nakuru Town along major roads.

Reagents

Nitric acid and perchloric acid used in this study were of analytical grade and were supplied by Hopkin and Williams Ltd, England. Commercial 1000 ppm standard solution Pb was purchased from Sigma chemical company. De-ionized water was also used for sample preparation, dilution and rinsing apparatus prior to analysis.

Cleaning of Glassware and Apparatus

All glassware were cleaned with detergent and hot water, rinsed several times with tap water and then soaked for 12 hours in 10% analytical grade nitric acid solution. Finally they were rinsed with distilled de-ionized water and dried in the oven at 105 ºC. The plastic containers were cleaned with detergent and tap water, soaked in 1:1 nitric acid and water overnight and rinsed thoroughly with distilled de-ionized water. They were then dried in an open rack and stored safely in a locked dust free storage area.

Sample collection

Soil samples

The samples were obtained from 10 farms randomly selected along roadsides within 5 km stretch of the roads. Other soil samples will be collected within 1 km far away from the roads. The soil samples were taken from a depth of 0-30 cm which represents the plough layer and average root zone for nutrients uptake and heavy metals burdened by vegetable plants (Nyangababo and Hamya, 1986). In each farm, ten sub-samples were randomly collected and then mixed thoroughly in to one composite sample to get a representative sample of that farm weighing about 1 kg. The sample was then placed in a polythene bag, sealed and labeled appropriately. A total of 10 soil samples from vegetable farms along the road sides were collected. In the laboratory, soil samples were dried in an oven at 80 ºC to a constant weight, ground using a mortar and pestle, then passed through a 2 mm sieve and stored in labeled containers awaiting further analysis.

Digestion of Samples for selected heavy metal analysis using AAS

The samples were digested following the procedure recommended by the (AOAC, 1990). One gram of dried sample was placed in 250 ml digestion tube and 10 ml of concentrated nitric acid added. The mixture was boiled gently for 30-45 minute. After cooling, 5 ml of 70% perchloric acid was added and the mixture boiled gently until dense white fumes appeared. Then 20 mL of distilled water was added and the mixture was boiled further to release any fumes. The solution was cooled further and filtered through Whatman No. 42 filter paper into a 50 ml volumetric flask. The filtrate was made to the mark using distilled water.

Calculation of concentrations of selected heavy metals in soil and vegetable samples

The concentration calculations were carried out using the calibration curve method, and worked out as follows:

$$\mu g / g = \frac{CDS}{Dry\ weight\ in\ grams}$$

where C = measured concentration in ppm
D = dilution factor
S = sample volume in ml.

Preparation of stock and standard solutions

Commercial standards of 1000 µg/g concentration were diluted and standards of concentrations of 0 - 10.0 µg/g were prepared.

Preparation of reference standards and blank

Reference material IAEA-433 was used. The reference material solutions were prepared using the same procedure as the sediment samples. The blank was prepared using distilled/de-ionized.

Method detection limit and recovery test

The calibration curves were established by a plot of absorbance readings against the corresponding concentration of standards. The absorbance readings and concentration of standards were used to calculate the correlation coefficients (r). The method detection limits and method of quantification were calculated using the equation below:

$$MDL / MQL = \frac{3\,x\ SD\,of\ blank\ reading}{slope}$$

The accuracy of the analytical procedure was investigated by spiking a 10 ml aliquot of 5 µg of lead into a conical flask containing 1.0 g of the vegetable sample. The same digestion procedure was followed for non-spiked and spiked samples side by side. Each sample was analyzed for their respective spiked metals by atomic absorption spectrophotometer and the percentage recovery calculated using the following equation.

$$\% R = \frac{C_{spiked} - C_{nonspiked}}{Amount\ added}$$

Determination of levels of selected heavy metals using AAS

Determination of levels of lead (Pb) was done in three replicates using computerized Varian Atomic Absorption Spectrometer model AA-10 (Varian manufacturing co. ltd, Australia). The calibration of the instrument was done using the prepared standards and blank solutions.

Data analysis

Mean values obtained for Pb from the sampled sites were compared by One-Way ANOVA at 95% level using SPSS 21 for windows assuming that there were significant differences among them when the statistical comparison gave $p < 0.05$. Pearson's correlation analysis was used to investigate the existence of a linear relationship between metal concentration in vegetables and in the soil.

Results and Discussion

Concentrations of Heavy Metals in Roadside Soil Samples

Analysis of soil samples for Pb content showed the presence of lead in all soil samples from eight sampling sites. The concentration of lead in soil samples with respect to distances from the road within the sampling area of Nakuru in Kenya is presented in Figure 2.

Figure 2 below indicates an exponential decrease in concentration of lead with distance from the main road. The values of lead in soil samples ranged from 1.01 to 130 mg/Kg. The graph indicates high values of lead in soil sampled at 20 meters from the busy main roads and low concentration of lead in soil sampled at 100 meters away from the road in the respective areas. There is a corresponding high level of lead in Eldoret – Nakuru – Ngata road and Nakuru – Nairobi - Free Area as compared to Kipande roads due to the high traffic in the roads. A similar observation is indicated in Figure 3 below of concentration of lead in vegetable samples with respect to distance from the main roads. Vegetables had high concentration of lead at a distance of 20 meters which decreases exponentially to approximately 0.04 mg/Kg.

The results are in agreement with studies done in other countries like Australia, Tanzania, Nigeria and in South Africa (Giannouli et al., 2007). The levels of measured lead in both soil and vegetable samples were higher than the recommended values by U.S EPA (2011).

The study also indicates that consuming vegetables grown along Eldoret – Nakuru, Kipande and Nakuru – Nairobi roads do have high concentrations of lead which is a health hazard as its high levels are able to affect the IQ of growing children.

It is known that Pb is a useful element in industry but its high levels may be toxic to both humans and animals when its concentration exceeds the safe limits, and its concentration in some human tissues such as thyroid can be changed depending on the tissue state. The highest Pb concentrations at 20 meters from the road may be attributed to heavy traffic within the roads of interest, while the lowest concentrations at 100 meters may be attributed to the aerial deposition of lead from vehicular fumes or due to water and surface runoff or deposition from the main roads. Fumes from vehicles using the roads are the major source of lead in soil and vegetable samples.

Lead, which is of most concern in environmental heavy metal pollution exhibited high levels in collected samples close to the high way.

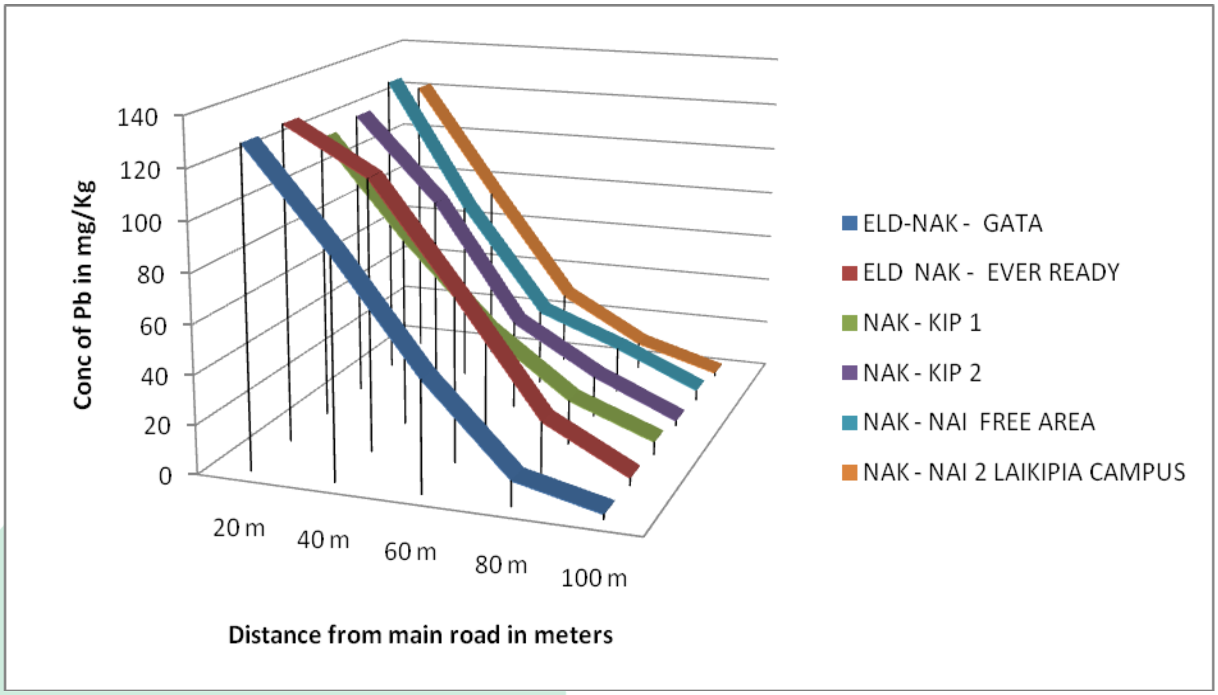

Figure 2: A graph showing exponential decrease of concentration of Pb with distance in soil samples.

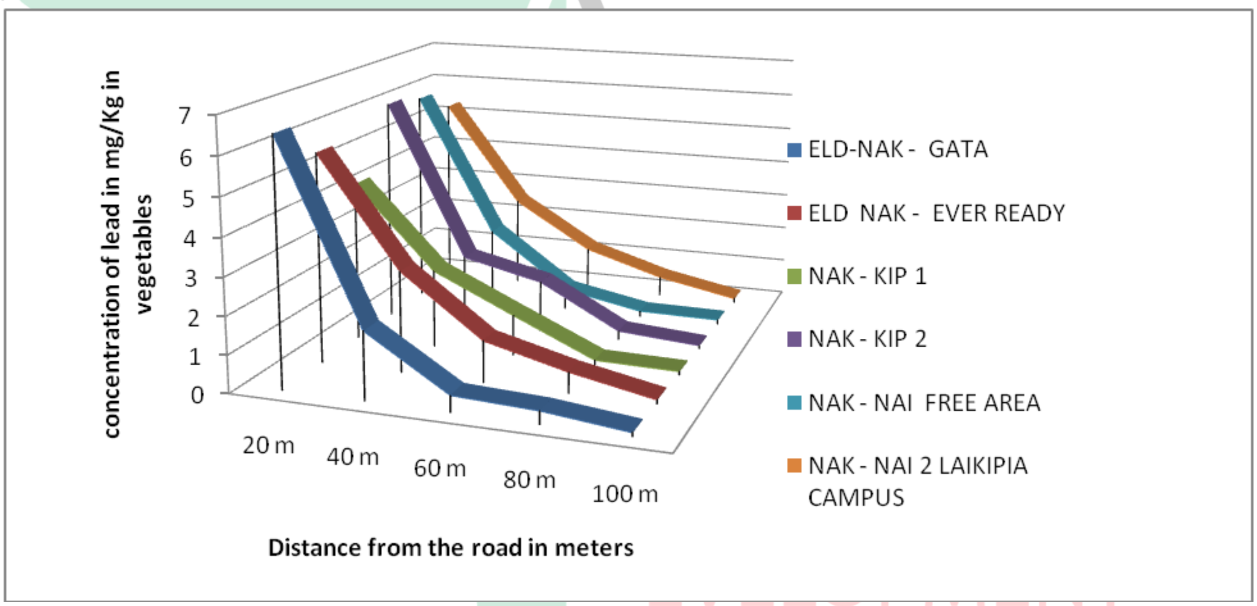

Figure 3: A graph of concentration of lead in vegetable samples and distance from the road.

Conclusion

The findings in this research shows that the lead contamination levels are higher along main roadside i.e. above the permissible levels according to the WHO. The levels of lead are highest in soil and vegetable samples collected at 20 m from the road side and decreased exponentially as distance increases from the road within Eldoret to Nakuru road, Kipande road and Nakuru Nairobi road. This could be attributed to vehicular emissions. The use of leaded gasoline can also be said to contribute to high levels of lead emissions to the atmosphere. The results imply vegetables grown along the busy roads may be a major source of lead to human beings.

Recommendation

The findings of this study presented a preliminary survey on the extent of Pb contamination of soils and vegetables and therefore recommend the following:

a) The government of Kenya should formulate a policy to control farming alongside roads.
b) Farmers should be sensitized to the dangers of growing food crops along major roads in Kenya especially on the public health aspect.
c) The study also recommends more study to be done extensively along other major roads in Kenya.

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